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TECHNICAL REPORT

INVESTIGATION OF METHODS FOR IMPROVING THE FRICTIONAL PROPERTIES OF RUBBER COMPOUNDS USED IN FOOTWEAR

by

P. J. Mahoney

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Previous work has shown that no specific type of rubber provides inherent superior frictional properties over others, and that wet or dry lubrication on contact surfaces drastically reduced the friction of all compounds. Efforts to improve frictional qualities entailed the testing of various tread designs, additive materials such as cork and cotton flock, composite specimens, and channeled and siped specimens. Tests were also conducted at room temperature and in some cases at 0°F.

The data obtained show (1) changes in tread design, composites and coarse additive materials are ineffective in improving friction on smooth surfaces; (2) siping of flat specimens showed slight improvement of friction on wet surfaces; (3) compounds that resist hardening at 0°F show better retention of friction at that temperature; and (4) the order of skid resistance of several compounds changes when tested on a different surface.

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Soles (Footwear)	4		4			
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Composite materials	10		6			
Siping	10		6			
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July 1971

Clothing and Personal Life Support Equipment Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

FOREWORD

This report covers the continuation of work reported under US Army Natick Laboratories In-House Laboratory Task 69, Project No. 1T011101A91A07. The purpose of the project was to use the instruments developed in the previous work for evaluating methods of improving the friction of rubber sole and heel compounds either by the use of additives to impart slip resistance or by modifying the surface of vulcanized rubber to improve frictional properties.

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ABSTRACT

Previous work has shown that no specific type of rubber provides inherent superior frictional properties over others, and that wet or dry lubrication on contact surfaces drastically reduced the friction of all compounds. Efforts to improve frictional qualities entailed the testing of various tread designs, additive materials such as cork and cotton flock, composite specimens, and channeled and siped specimens. Tests were also conducted at room temperature and in some cases at $0^{\circ}F$.

The data obtained show (1) changes in tread design, composites and coarse additive materials are ineffective in improving friction on smooth surfaces; (2) siping of flat specimens showed slight improvement of friction on wet surfaces; (3) compounds that resist hardening at $0^{\circ}F$ show better retention of friction at that temperature; and (4) the order of skid resistance of several compounds changes when tested on a different surface.

INVESTIGATION OF METHODS FOR IMPROVING THE FRICTIONAL PROPERTIES OF RUBBER COMPOUNDS USED IN FOOTWEAR

I. Introduction

The development of one apparatus and the modification of another, for determining the frictional properties of rubber polymers has been described in detail in previous work conducted at the US Army Natick Laboratories(1). The first apparatus consists of a four-wheeled weighted cart on rails (Figure 1). Its speed is regulated by the distance traveled down an inclined plane. A rubber specimen mounted at a 20^{o} angle below the rear axle of the cart lifts the rear wheels off the rails on contact with a horizontal test surface, and thus acts as a brake to stop the cart. The distance traveled by the cart after contact of the test specimen with the test surface is taken as a comparative measure of the frictional properties of the rubber. Specimens with the highest frictional properties stop the cart in the shortest distance. For example, data obtained show that the skid distances of most rubber compounds on waxed asphalt tile fell between 14 and 16 inches at a contact speed of 4 m.p.h. and a load of approximately 150 p.s.i. These figures can be accepted as representative since the materials tested were typical of those used in commercial soles and heels. When the tile surface was dusted, the skid distance of the test compounds increased to values between 35 and 45 inches. When the tile was wet, none of the specimens stopped the carriage within the limits of the test track and in these cases, the decrease in carriage speed was measured. In most cases, speed dropped from initial contact at 4 m.p.h. to between 2.5 and 3.5 m.p.h., depending on the rubber tested.

The second apparatus used for measurement of friction was a modified commercial instrument, the Stanley Portable Friction Tester (Figure 2). This instrument consists of a pendulum, the end of which holds a test specimen in a spring-loaded arm. The pendulum is adjusted to give a 5-inch long contact between the specimen and the test surface at the bottom of its swing. The skid resistance index is read directly from an arbitrary scale by means of a pointer carried along with the pendulum arm to the highest point of swing and a higher reading denotes better skid resistance. Readings with this instrument on waxed tile ranged from 105 to 80. On dusted tile, pendulum readings dropped to the 45 to 35 range and on wet tile dropped to an extremely low 9 to 4 range. A comparison of the two instruments is given in Table I.

Data obtained using these instruments to test various rubber compounds are also included in previous work(1). The compounds chosen were representative of those used in the manufacture of rubber soles and heels and were designed to give a range of hardnesses and resiliences. Test results showed no direct correlation between friction and either property, although there was a general tendency for softer compounds to show higher friction. Further, no specific type of rubber showed inherent frictional superiority over the others, and wet or dry lubrication on contact surfaces drastically reduced the friction of all the compounds.

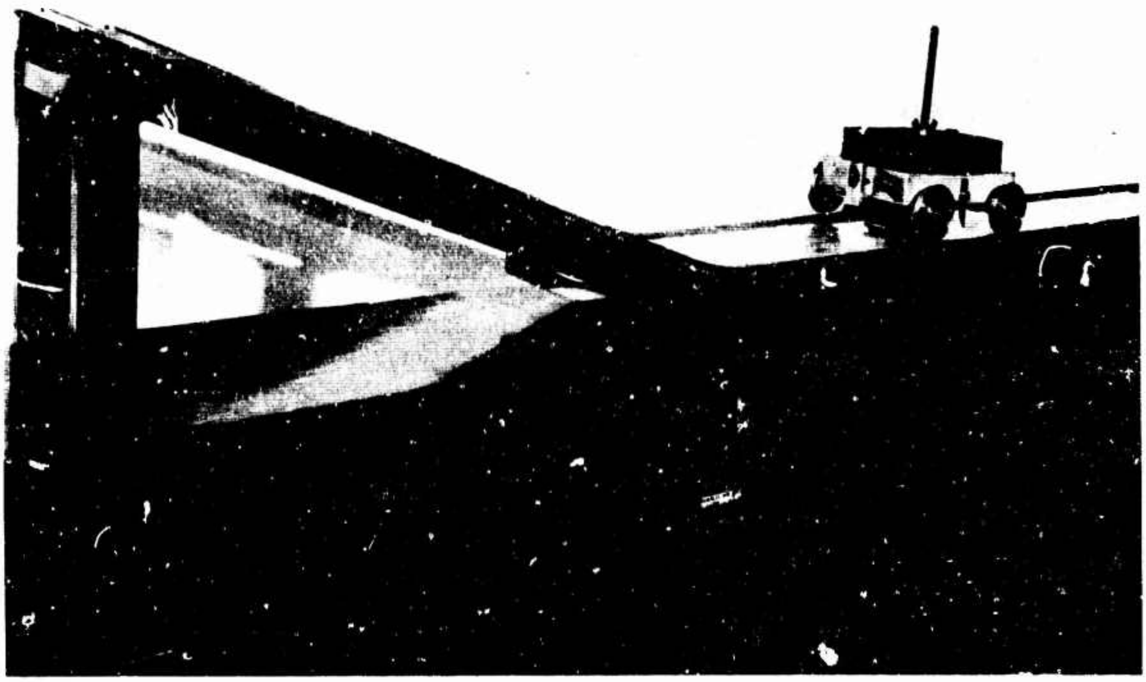

Figure 1. Inclinded Plane and Carriage Tester

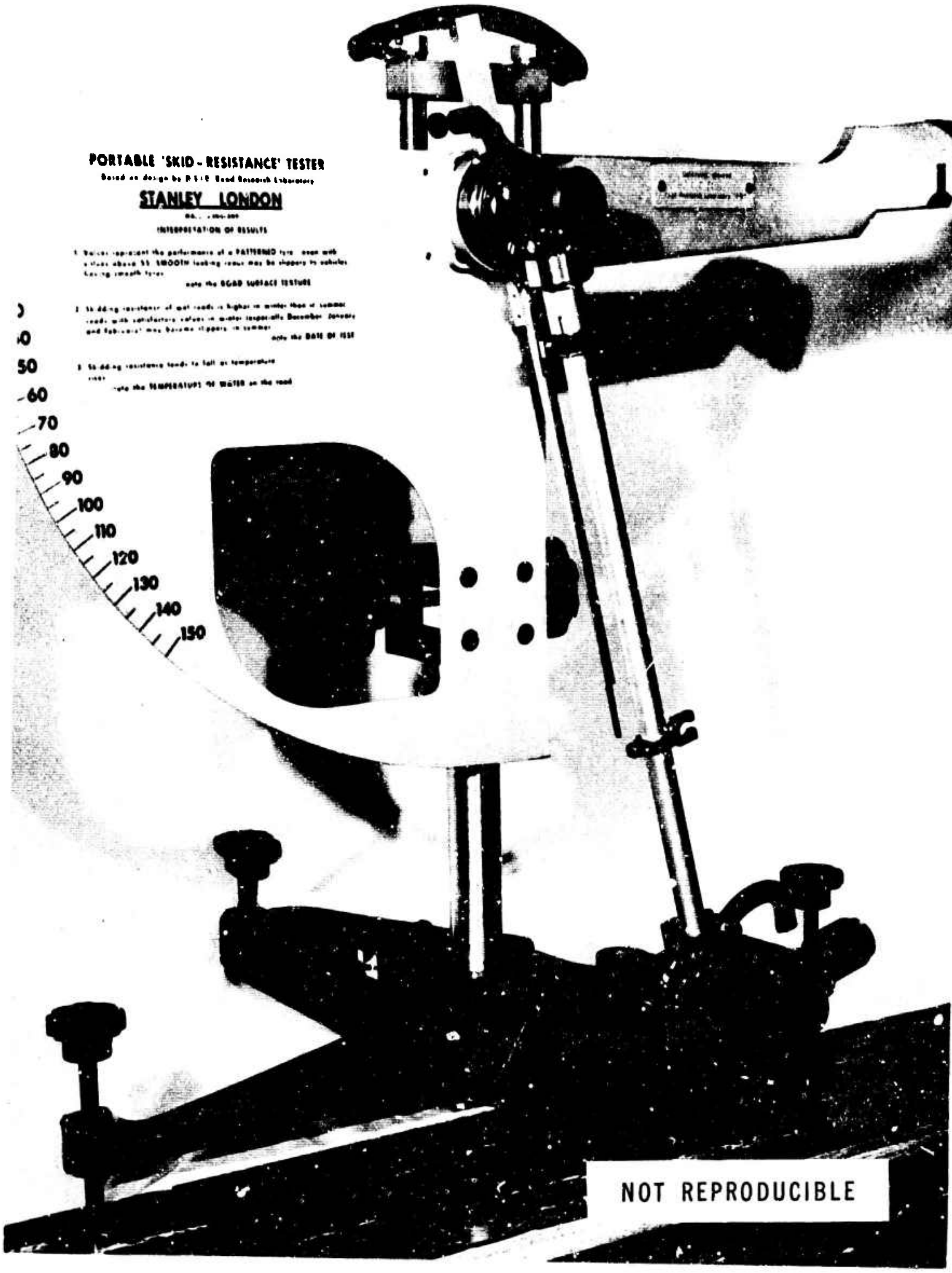

Figure 2. Stanley Portable Skid Resistance Tester

The work reported here was initiated to use these instruments for evaluating possible methods of improving the friction of rubber sole and heel compounds, either by the use of additives to impart slip resistance or by modifying the surface of vulcanized rubber to improve frictional qualities.

II Test Methods

Friction, Pendulum; or Inclined Plane and Carriage	See Reference No. 1
Hardness	ASTM D2240-64T
Resilience	ASTM D2632-67

III Test Program and Test Results

A. Frictional Properties of Direct Molded Soling (DMS) Compounds

To obtain data on the types of soling materials suitable for use in the direct molded sole (DMS) production of Army combat footwear, the following rubbers, representing standard and experimental compounds were tested: SBR; neoprene; nitrile rubber; nitrile/vinyl polyblend; and a microcellular compound based on a blend of nitrile/vinyl and polybutadiene. Test specimens were taken from boots and were cut and buffed to the same size as the molded specimens used in previous work (1 inch by 1 inch by 7/16-inch). Pendulum skid results on these materials using waxed tile, dusted tile and wet tile as the test surfaces are listed in Table II.

B. Additive Materials

For many years, sole and heel producers have added materials to rubber compounds to improve cut resistance, stitching properties and to impart s[illegible] resistance. Accordingly, compounds were prepared for test using various amounts of cork, ground walnut shell, cotton flock and combinations of these materials which are typical of these additives. The frictional properties of these compounds evaluated by both the pendulum machine and the inclined plane and carriage are listed in Tables III and IV. Recipes used to prepare the base compounds are given in Appendix I.

C. Effect of Tread Design and Specimen Width

All previous work had been conducted using a one inch wide smooth surface specimen (molded or buffed) to determine the properties of the particular compound and rubber under investigation. This phase of the work was undertaken to determine the effect of the sole tread design; i.e., DMS lug design, DMS chevron design, and Navy molded deck sole design on various test surfaces.* For this work, a 3-inch wide specimen holder was made so that a more representative portion of the tread design would be tested. Tests were also conducted on the same compounds using 1 inch

*Details of these designs are shown in specifications MIL-B-43154D, MIL-B-43481 and MIL-O-836, respectively.

wide and 3-inch wide smooth specimens for comparison purposes. This comparison is shown in Table V. Frictional properties of various tread designs are given in Table VI. First tests, with the specimen contacting the sliding surface at a 20 degree angle, gave erratic results. Therefore, in some tests, the specimen was mounted so that the entire 3-inch by 1-inch face contacted the test surface. On some specimens, the tread design was buffed to determine the effect of increased contact area.

D. Composite Specimens

Surfaces of commercial soles are often pebbled or embossed with shallow rough textures for the purpose of improving grip on the walking surfaces. These are quickly worn away. To provide a material that would maintain surface roughness even after wear, composite specimens were prepared consisting of two varying compounds: a low hardness, low abrasion compound and a high hardness, high abrasion compound. Slabs of each compound were cured and then chopped in a Wiley mill, using a No. 10 screen. Various amounts of one chopped material were then added to uncured portions of the other compound on a rubber mill. Milling was continued only long enough to disperse the particles, and the mill rolls were open sufficiently to avoid further breakdown of the added particles. Thus, specimens were prepared having different amounts of chopped soft compound in a hard matrix and different amounts of chopped hard compound in a soft matrix. Physical properties of the compounds are given in a Memorandum Report[2]. Carriage skid distances for these specimens are listed in Table VII.

E. Channeled and Siped Specimens

It is sometimes claimed that the grip of soles designed for use on wet surfaces can be improved by incorporation of channels in the rubber to allow surface water to flow away, thus increasing contact between the sole and the surface. The frictional properties of channeled surfaces were evaluated by cutting canals approximately 1/16-inch wide, 1/8-inch deep, and 1/2-inch apart in a square design; that is, with the canals parallel and at right angles to the direction of travel, and in a diamond pattern with the canals at a 45° angle to the direction of travel. Materials used were an SBR hard soling material (FP-21), a natural rubber cork mixture, an SBR cork mixture and a 20 hardness silicone rubber. Test results are listed in Tables VIII and IX. The compound recipes are listed in Appendix I.

On automotive tires, a technique called siping is sometimes used with the intention of achieving better traction. This involves making very fine, closely-spaced cuts on the tread surface. Specimens of natural rubber (FP-1), neoprene (FP-24), and nitrile (FP-5) compounds were siped with cuts 1/16-inch and 1/8-inch apart, made with a sharp single edge razor blade equipped with 1/8-inch wide guides adhered to the side of the blade to regulate cut depth to 1/16-inch and 1/18-inch. Cuts were made parallel, at 45° and at 90° to the direction of travel. Specimens were tested on waxed tile and on wet tile and the results are listed in Table X. Compound recipes are given in Appendix I.

F. Pendulum Skid Tests at 0°F

It is generally accepted that rubber soling compounds which harden at low temperatures suffer a loss in friction and grip. Previous skid tests on ice had been conducted using ice frozen in a tray by cooling coils. The ice temperature could be controlled but the test instrument and specimens were at room temperature. To overcome this, a temporary front was built for a Tenney low-temperature test cabinet, Model 27T, which permitted placement of instrument, test specimens, and test surface inside the cabinet so that they could be held at low temperatures. The pendulum tester could be operated through hand openings in this temporary front. Pendulum results on waxed tile at room temperature, at 0°F, and on ice at 0°F for various test compounds are listed in Table XI. Hardness readings on the specimens at room temperature and at 0°F are also given.

G. Frictional Properties of Experimental DMS Compounds

A number of experimental DMS compounds have been developed by these laboratories and evaluated for potential improvements in the abrasion resistance, low temperature flexibility or reduction in weight of combat footwear. Representative compounds of these were mixed in the laboratory and molded in both 1-inch and 3-inch wide specimens. Hardness and resilience properties and hardness change at 0° for these compounds are listed in Table XII. Carriage skid results on various test surfaces for 1-inch wide specimens are listed in Table XIII and for 3-inch wide specimens in Table XIV. Pendulum skid results for 1-inch specimens are listed in Table XV, and for 3-inch specimens in Table XVI. Compounding recipes given in Appendix II.

IV Discussion

A. Frictional Properties of Direct Molded Soling Compounds

Previous work on skid resistance had been conducted on laboratory mixed and molded test specimens. For comparison purposes, tests were conducted on specimens taken from commercial and experimental molded combat boots. The results obtained confirmed previous work, in which specimens showed drastically reduced friction properties on test surfaces lubricated with dust or water. Of the compounds tested, the experimental microcellular compound (a closed cell lightweight material based on nitrile/vinyl polyblend and polybutadiene) showed the highest friction on waxed tile and on wet tile and was intermediate on dusted tile (Table II).

B. Additive Materials

The additive materials, cork, flock and ground walnut shells, in general adversely affected the frictional properties of the base compound; the possible exception was the ground cork which in some cases exhibited properties equal to or slightly better than the base compounds in which it was used (Tables III and IV). The results in Table V show that a three-inch-wide specimen gives comparable results to those obtained with a one inch wide specimen on the sliding carriage apparatus. However, none of the results show any significant advantage by adding these materials to rubber for the purpose of increasing grip or traction.

C. Effect of Tread Designs

Three-inch wide specimens with their larger surface contact were used to evaluate the effect of irregular rubber surfaces, such as those found on soles with lugged or chevron designs. The results listed in Table VI show no clear cut superiority of one design over another. They do show however, that, on a smooth surface, such as waxed asphalt tile, greater contact between the rubber and the test surface results in higher friction. This is shown by the increase in skid resistance of the irregular sole surfaces after buffing. It is also shown by the shorter skid distance of the smooth surfaced commercial cork sole compared with those of the lugged and SBR chevron sole (16.6 inches vs. 19.5 and 20.2 inches), for example. Any interference by a lubrication layer of dust or water again shows a reduction in friction of all surfaces. These behaviors can be explained, in part at least, by the contribution of the adhesion component of friction. Thus, the larger the amount of contact surfaces, the greater the strength of the attractive forces between them and the higher the friction, and any layer interfering with surface contact diminishes that friction.

D. Composite Specimens

No general improvements in skid properties was evident in the testing of composite materials which were mixtures of a high hardness, high abrasion compound and a low hardness, low abrasion compound. The results listed in Table VII show that addition of hard particles to a soft stock gave no real improvement on wet tile and resulted in a decrease in friction on waxed tile and concrete. Soft particles in a hard matrix caused a decrease in friction on wet tile, little change on concrete and some improvement on waxed tile but not enough to warrant adoption of the material for sole and heel use.

E. Channeled and Siped Specimens

Tables VIII and IX give results of tests conducted on specimens in which channels were cut in the surface (in a square or diamond design) in an effort to improve wet skid resistance. Materials tested included a 60 hardness SBR, a 95 hardness SBR, a natural rubber cork mixture and an extremely soft silicone, rubber compound. The speed of contact using the carriage and inclined plane apparatus was 2.5 mph. No real indications of improved skid properties were evident, in the stocks at normal footwear hardnesses. Likewise, tests with the pendulum instrument with its contact speed of 6 mph showed no real improvement in friction on the test surfaces. The most favorable indications of improvement in friction on wet tile were shown by some siped specimens in Table X. Here specimens with shallow diagonal cuts were the only ones of all the various modifications and additives tested that actually stopped the test carriage within the 45 inch limit of the wet track under these test conditions. The speed of the carriage across the last 12 inches of track had dropped to as low as 2.07 mph from an initial speed of 4.0 mph. Thus siping, which provides many edges for contact with the sliding surface causes a definite improvement in friction on wet surfaces, at least in a sliding situation.

F. Pendulum Skid Tests at 0°F

Table XI reveals a definite relationship between skid resistance and hardness change on cooling from room temperature to 0°F. Compounds with a large increase in hardness show poor skid properties at low temperature. Even though no direct relationship has been found between hardness and anti-skid properties, compounds of 90 hardness or over are generally poor due to the poorer contact and lessening of the adhesion component between these very hard compounds and the sliding surface. In Table XI, all compounds that are in the 90+ hardness range at 0°F. have the poorest frictional properties at that temperature. Compounds that remain in the 60 hardness range show better anti-skid properties at 0°F, with the exception of one butyl compound. The data bears out the belief that rubber compounds which harden the least at low temperatures generally suffer less change in friction. The data also shows that friction on ice at 0°F is generally low, but again, the compounds that resist hardening retain better friction.

G. Frictional Properties of Experimental DMS Compounds

Tables XII through XVI list the results of extensive tests on DMS compounds for combat boots. The SBR compound and the nitrile/vinyl polyblend compound are presently in use on the all-leather and tropical boot, respectively. The nitrile, neoprene, and chloro-sulfonated polyethylene compounds are experimental compounds with increased abrasion resistance. The microcellular compound is an experimental lightweight soling (nitrile/vinyl and polybutadiene polymers) and the urethane polymer is an experimental cellular compound for low temperature use. The cellular materials were tested with the skin as the contacting surface and also with the skin buffed off. These materials were tested in both 1-inch wide and 3-inch wide test specimens using both test instruments, on various test surfaces, at room temperature and at 0°F.

The tables list the polymers in order of decreasing anti-skid properties for each test condition. They show that no one material is best on all sliding surfaces. For example, the microcellular compound was best on waxed tile, last on dusted tile, second best on concrete and next to last on wet tile (Table XIII). The buffed urethane polymer is next to last on waxed tile and last on concrete but the urethane with skin is best on dusted tile and the buffed urethane tops the list on wet tile. A similar pattern is shown on the pendulum tests (Table XV). The microcellular compound rates first on waxed tile but on wet tile, buffed microcellular (simulating a sole after some wear) rates first while microcellular with mold skin (new sole) is at the bottom of the list. On the pendulum tests at 0°F the microcellular and nitrile/vinyl polyblend compounds show poorly as would be expected from their large hardness increase (See Table XII) while the urethane compound which exhibits very little hardness change is on top of the list. Overall, however, all compounds have poor friction properties on dusted tile, wet tile and ice.

H. General Comments

In reviewing the results of this testing, it should be emphasized that rubber friction is generally considered to be made up of two and sometimes three components: an adhesion term, a deformation term and abrasion term. Under the conditions of this investigation, it appears that the predominant factor is the adhesion component resulting from the molecular attraction between the test surface and the rubber. It can be affected by many things; i.e., the hardness of the compounded rubbers; blooming of wax, plasticizer or antioxidant; irregularity of the rubber surface; and expecially lubrication of the sliding surfaces by dust or water. For example, in the tests on polymers especially compounded for direct molded combat boots, friction index on waxed tile had a variation of 12% from the highest (microcellular compound) to the lowest (nitrile/vinyl compound) Table XVI. On dusted tile, the average friction index of all compounds decreased 67% from the average index on waxed tile. On wet tile, the average friction index decreased 88% from the average on waxed tile.

The tests indicate that in contact with smooth flat surfaces a smooth flat rubber surface is desirable, that cutting channels in the rubber to improve traction on wet surfaces is generally inefficient, but that siping does improve friction on wet smooth surfaces, at least in a sliding or skidding situation. They also show that cellular compounds are good on some surfaces and that most compounds are poor on ice but that softer compounds have an advantage. Thus, an optimum design for combat footwear would include lugs for grip in soft earth or packed snow, plus an area of soft smooth rubber, possibly siped or microcellular under the ball of the foot and on the heel.

V. Conclusions

1. Smooth flat rubber surfaces give higher friction on smooth surfaces than do irregular pebbled surfaces or compounds containing coarse particle additives.

2. Channeling rubber surfaces does not improve friction on wet surfaces but siping does under some conditions.

3. Compounds that resist hardening at low temperatures generally retain higher friction at those temperatures.

4. Soft stocks generally improve surface contact and hence friction and microcellular compounds show superiority on some surfaces.

VI Recommendations

It is recommended:

1. That the conclusions listed above be considered in the design of soles

and heels for combat footwear and in the development of rubber compounds to be used in them.

2. That all new polymers and compounded stocks evaluated in the future for footwear soles and heels be tested for frictional properties.

VII References

1. Wilson, A. F., and P. J. Mahoney, Development of Techniques for Evaluating the Frictional Properties of Rubber Sole and Heel Compounds, 71-6-CE (C&PLSEL-77). U. S. Army Natick Laboratories, Natick, Mass., May 1970.

2. Lulka, L., Anti-Slip Rubber Composites, Memorandum Report. U. S. Army Natick Laboratories, Natick, Mass., 2 January 1970.

TABLE I

Comparison of Inclined Plane Apparatus and Modified Pendulum Apparatus

	Inclined Plane and Carriage	Modified Pendulum
Contact Speed	Variable from 2 to 5 M.P.H.	Fixed 6 M.P.H.
Contact Distance	Sample Dependent	5 inches
Contact Load	Constant in test but can be regulated from 5 to 50 lbs.	Varies in test from 0 to 5 lbs. to 0
Test Units	0 to 40 inches, or 0 to 5 M.P.H.	150 to 0, arbitrary units
Availability	Built at NLABS	Commercial

TABLE II

Pendulum Skid - Specimens Cut from DMS Combat Boots

1-inch Specimens Buffed

Polymer	Skid Index: Waxed Tile	Skid Index: Dusted Tile	Skid Index: Wet Tile
SBR	87	36	17
Neoprene	82	35	15
Nitrile	89	36	18
Nitrile/Vinyl Polyblend	61	56	10
Microcellular	104	39	20

TABLE III
Frictional Properties of Polymers with Additives
Carriage Skid Values (4 M.P.H., 30 lb. Weight, 1-Inch Wide Specimens)

Polymer	Additive Material	Skid in Inches on Waxed Tile	Dusted Tile	Cement
Natural Rubber	None	12.7	43.5	17.4
Base FP-1	10% Ground Shell	14.6	42.0	16.9
	20% Ground Walnut Shell	16.6	--	--
	10% Cotton Flock	14.5	41.2	21.6
	20% Cotton Flock	17.9	40.5	24.6
	Flock & Clay	17.0	40.6	22.4
	10% Cork	13.2	43.7	18.4
	Flock & Cork	16.7	34.8	--
	Cork and Walnut Shell	19.0	40.0	--
	Flock & Walnut Shell	19.0	40.0	--
	18% Cork	12.5	42.5	--
SBR Base (FP-2)	None	14.0	40.7	17.5
	5% Cork	13.6	39.2	19.1
	20% Cotton Flock	19.4	34.0	22.4

TABLE IV

Frictional Properties of Polymers with Additives
Pendulum Skid Index

Polymer	Additive Material	Skid Index on Waxed Tile	Skid Index on Dusted Tile	Skid Index on Wet Tile
Natural Rubber	None	98	34	5
	10% Ground Walnut Shell	88	34	8
	10% Cotton Flock	82	34	10
	20% Cotton Flock	66	33	11
	Flock and Clay	78	32	9
	10% Cork	95	33	12
SBR	None	89	33	8
	5% Cork	86	33	8
	20% Cotton Flock	55	36	13

TABLE V

Frictional Properties of Polymers with Additives

Comparison of Carriage Skid Values on
Waxed Tile with 1" vs. 3" wide Specimens

Material	1-inch specimen	3-inch specimen	Difference
SBR-65 Hardness (FP-2)	13.8	14.0	+0.2
SBR-95 Hardness (FP-21)	24.5	19.0	-5.5
Natural Rubber + 10% walnut shell	14.6	14.7	+0.1
Natural Rubber + 20% walnut shell	16.6	16.8	+0.2
SBR + cotton flock	19.4	17.8	-1.6
Natural Rubber + cotton flock	14.5	16.3	+1.8
Natural Rubber, cork, flock	16.7	15.9	-0.8
Natural Rubber, flock, shell	19.0	18.6	-0.4
Natural Rubber, cork	16.9	16.7	-0.2

TABLE VI

Frictional Properties of Patterned Soles

Carriage Skid (4 M.P.H., 30 lb. Weight 3-inch wide specimens)

Specimen	Skid Distance - inches Waxed Tile	Skid Distance - inches Dusted Tile	Speed at Track End, M.P.H. Wet Tile
Calendered Sole	20.8	29.6	2.80
Calendered Sole - Buffed	14.5	--	--
Molded Deck Sole	21.4	34.4	2.70
Molded Deck Sole - Buffed	15.8	--	--
Molded Deck Sole - Mounted Flat	17.7	31.5	2.26
SBR Chevron Sole	20.2	37	2.71
SBR Chevron - Buffed	14.7	--	--
SBR Chevron Sole - Mounted Flat	21.3	27.5	2.91
Neoprene Chevron Sole	20.1	--	--
Neoprene Chevron Sole - Buffed	15.0	--	--
Lug Sole (Nitrile/Vinyl Polyblend)	19.5	35	2.78
Lug Sole - (Nitrile/Vinyl Polyblend)-Buffed	16.8	--	--
Commercial cork sole	16.6	42.0	2.81

TABLE VII

Frictional Properties of Composite Materials

Carriage Skid (4 M.P.H., 30 lb. Weight, 1-inch wide specimens)

Specimen	Skid Distance (inches) Waxed Tile	Skid Distance (inches) Concrete	Speed at Track End, M.P.H. Wet Tile
Soft Material	13.1	17.9	3.44
30% Cured Hard/70% Soft	15.3	18.9	3.43
50% Cured Hard/50% Soft	16.4	19.2	3.41
70% Cured Hard/30% Soft	16.8	19.5	3.48
Hard Material	16.7	19.2	3.29
30% Cured Soft/70% Hard	16.1	19.1	3.44
50% Cured Soft/50% Hard	15.9	19.0	3.48
70% Cured Soft/50% Hard	15.0	18.6	3.46

TABLE VIII

Frictional Properties of Channeled Specimens (30 lb. Weight
2.5 M.P.H. - 3 Inch Specimens
(Carriage Skid)

Specimen	Waxed Tile	Skid Distance - Inches Dusted Tile	Wet Tile
FP-21 Hard Soling Shore A = 95			
Smooth	9.1	12.8	23.1
1/2" Squares	10.1	15.8	21.9
1/2" Diamond	8.9	14.2	23.6
Natural Rubber - Cork Shore A = 58 (FP-1 Compound + 10% Cork)			
Smooth	6.0	17.0	16.5
1/2" Squares	7.0	17.9	18.4
1/2" Diamond	7.0	17.1	17.1
SBR Cork Shore A = 60 (FP-2 Compound + 10% Cork)			
Smooth	6.1	16.0	18.5
1/2" Squares	7.5	17.3	20.2
1/2" Diamond	6.9	17.0	20.2
#7220 Silicone Shore A = 20			
Smooth	9.4	17.7	2.39 M.P.H.*
1/2" Squares	6.6	17.0	2.19 M.P.H.*
1/2" Diamond	6.6	16.7	15.4

* Speed at track end; specimen did not stop cart on track

TABLE IX

Pendulum Index of Smooth and Channeled Surfaces
(3-inch specimens)

Specimen	Waxed Tile	Wet Tile
SBR Hard Soling Compound (FP-21)		
Smooth	70	12
Square design	68	12
Diamond	56	9
Natural Rubber/Cork		
Smooth	85	20
Square design	89	19
Diamond design	91	17
SBR/Cork		
Smooth	83	17
Square design	77	14
Diamond design	80	15
20 Hardness Silicone		
Smooth	93	6
Square design	90	7
Diamond design	80	10

TABLE X

Frictional Properties of Siped Specimens Carriage Skid
(30 lb. Weight., 4 M.P.H.)

		Specimens Cut 1/8" Deep, 1/8" Apart		
		Skid on Waxed Tile 3" wide specimen (inches)	Skid on Wet Tile[1] 1" wide specimen (M.P.H.)	3" wide specimen (M.P.H.)
Natural Rubber (FP-1)	None	13.3	3.50	2.84
	Travel Direction	13.2	2.49	3.11
	Across Tr'vl Direction	--	2.18	--
	Diagonal	17.9	2.98	2.41
Nitrile (FP-5)	None	15.0	3.34	2.96
	Travel Direction	14.3	2.66	3.10
	Across Tr'vl Direction	--	3.01	--
	Diagonal	17.5	3.23	2.72
Neoprene (FP-24)	None	13.8	3.50	2.90
	Travel Direction	13.0	3.29	2.90
	Across Tr'vl Direction	--	2.78	--
	Diagonal	16.5	3.06	2.17 40.6"
		Specimens Cut 1/16" Apart		
Natural Rubber (FP-1)	None	--	--	3.01M.P.H.
	Diag. 1/8" deep	--	--	36.3"*
	Diag. 1/16" deep	--	--	35.0"*
Neoprene (FP-24)	None	--	--	2.75 M.P.H.
	Diag. 1/8" deep	--	--	2.07 M.P.H. 44.3"
	Diag. 1/16" deep	--	--	2.70 M.P.H.

* Only those specimens marked with * stopped on track

Note (1) Most specimens do not stop within track length. Figure listed is speed at 40 inches with initial speed of 4 M.P.H.

TABLE XI

Change in Pendulum Skid of Test Compounds at Low Temperatures

Base Polymer	Hardness at R.T. 0°F.	PTS Change	Skid Index Waxed Tile at R.T.	Skid Index Waxed Tile at 0°F.	Ice at 0°F.
Polybutadiene	(62 - 65)	3	89	90	45
Natural Rubber	(54 - 58)	4	88	95	35
SBR	(95 - 100)	5	42	45	10
Natural Rubber	(59 - 65)	6	90	92	35
Polyisoprene	(61 - 68)	7	94	82	28
EPDM	(62 - 70)	8	78	80	27
Natural Rubber Cork	(53 - 62)	9	104	77	30
Butyl	(52 - 65)	13	91	60	18
SBR	(62 - 78)	16	84	58	14
Neoprene	(60 - 77)	17	87	58	15
Chloro-sulfonated Polyethylene	(75 - 92)	17	66	47	10
Nitrile	(70 - 96)	26	72	39	6
Nitrile/Vinyl Polyblend	(65 - 98)	33	63	36	6

TABLE XII

Experimental DMS Compounds
Physical Properties

Polymer [1]	Hardness	Resilience	Hardness Change 2 Hrs @ 0°F
SBR (SBR-1)	65	37	+10
Nitrile/Vinyl Polyblend (NV-2)	69	15	+26
Nitrile (NBR-3)	60	39	+12
Neoprene (CR-4)	59	33	+10
Chloro-sulfonated Polyethylene (CSP-5)	60	39	+20
Microcellular (skin) (Micro-6)	56	23	+35
Microcellular (buffed)	56	20	+35
Urethane Cellular (skin) (UC-1)	71	48	+1
Urethane Cellular (buffed)	55	57	+1

Note [1] - See Appendix II for compound formulae. Chlorosulfonated polyethylene and urethane specimens were industrial formulation.

TABLE XIII

Experimental DMS Compounds Carriage Skid
(30 lb. Weight, 4 M.P.H., 1 inch Wide Specimens)

Order of Skid Resistance on Different Surfaces

Waxed Tile (Inches)	Dusted Tile (Inches)	Concrete (Inches)	Speed at Track End Wet Tile (M.P.H.)
Microcellular 13.3"	Urethane (Skin) 28.0	SBR 17.7	Urethane (Buffed) 2.72
Microcellular 14.0" (buffed)	Nitrile/Vinyl 32.5 Polyblend	Micro- 18.0 cellular	SBR 3.06
Nitrile 14.0"	SBR 34.5	Neoprene 18.0	Micro- 3.06 cellular (buffed)
SBR 14.5"	Urethane 37.0 (buffed)	Micro- 18.5 cellular (buffed)	Nitrile/Vinyl Polyblend 3.25
Neoprene 15.4"	Nitrile 38.6	Nitrile/Vinyl Polyblend 18.5	Chloro-sulfon- 3.38 ated Polyethylene
Chloro-sulfonated Polyethylene 16.0"	Micro- 38.8 cellular	Nitrile 18.5	Urethane (skin) 3.39
Nitrile/Vinyl Poly-blend 16.3"	Neoprene 40.0	Chloro-sulfonated Polyethylene 20.0	Neoprene 3.39
Urethane cellular (buffed) 16.5"	Chloro-sulfonated Polyethylene 42.0	Urethane 20.0 (skin)	Microcellular 3.41
Urethane cellular (skin) 18.5"	Microcellular 44.5	Urethane 20.6 (buffed)	Nitrile 3.53

TABLE XIV

Experimental DMS Compounds Carriage Skid
(30 lb. Weight, 4 M.P.H. 3" Wide Specimens)

Order of Skid Resistance on Different Surfaces

Waxed Tile		Dusted Tile, Inches		Wet Tile, M.P.H.	
Microcellular	12.8"	Nitrile/Vinyl Polyblend	33	Microcellular (buffed)	2.89
Nitrile	13.3"	Neoprene	34.5	SBR	2.91
SBR	13.5"	Nitrile	35.0	Nitrile/Vinyl Polyblend	3.17
Microcellular (buffed)	13.6"	Chloro-sulfonated Polyethylene	35.3	Neoprene	3.19
Chloro-sulfonated Polyethylene	14.3"	SBR	35.5	Chloro-sulfonated Polyethylene	3.23
Neoprene	14.5"	Microcellular	39.0	Nitrile	3.26
Nitrile/Vinyl Polyblend	14.9"	Microcellular (buffed)	40.6	Microcellular	3.42

TABLE XV

Experimental DMS Compounds
Pendulum Skid Index

Order of Skid Resistance on Different Surfaces
One Inch Wide Specimens

Waxed Tile	Dusted Tile	Concrete	Wet Tile	Waxed Tile at 0°F	Ice at 0°F
Micro-cellular 108	Nitrile/Vinyl Polyblend 35	SBR 77	Microcellular (buffed) 16	Urethane Cellular 60	Urethane Cellular (buffed) 35
Micro (buffed) 101	SBR 33	Neoprene 77	Urethane Cellular (buffed) 14 SBR 11	Urethane Cellular (buffed) 55	Urethane Cellular 15
Nitrile 89	Nitrile 32	Microcellular (buffed) 77	Nitrile/Vinyl Polyblend 8	Microcellular 50	Neoprene 13
Urethane Cellular (buffed) 85 SBR 83	Chlorosulfonated Polyethylene 32	Nitrile 74	Urethane (skin) 8 Nitrile 7	Chloro-sulfonated Polyethylene 50	Nitrile 11
Chloro-sulfonated Polyethylene 83	Microcellular 32	Chlorosulfonated Polyethylene 74	Neoprene 7	Nitrile 34	Chloro-sulfonated Polyethylene 10
Neoprene 79	Microcellular (buffed) 32	Microcellular 74 Nitrile/Vinyl Polyblend 73	Chloro-sulfonated Polyethylene 7	SBR 30	SBR 10
Nitrile/Vinyl Polyblend 73	Urethane Cellular (skin) 32	Urethane Cellular (buffed) 70	Microcellular 6	Neoprene 18	Microcellular 9
Urethane Cellular (skin) 68	Urethane Cellular (buffed) 32	Urethane Cellular 62		Nitrile/Vinyl Polyblend 15	Nitrile/Vinyl Polyblend 5
	Neoprene 31			Microcellular (buffed) 12	

TABLE XVI

Experimental DMS Compounds Pendulum Skid Index

Order of Skid Resistance on Different Surfaces

3-inch wide specimens

Waxed Tile		Dusted Tile		Concrete		Wet Tile	
Microcellular	114	Nitrile/Vinyl Polyblend	37	Microcellular (buffed)	86	Chloro-sulfonated polyethylene	18
Nitrile	112	SBR	36	SBR	85	SBR	14
SBR	112	Nitrile	35	Nitrile	84	Microcellular (buffed)	13
Microcellular (buffed)	106	Neoprene	35	Microcellular	82	Neoprene	13
Chloro-sulfonated polyethylene	102	Chloro-sulfonated polyethylene	35	Neoprene	82	Nitrile	12
Neoprene	100	Microcellular	34	Nitrile/Vinyl Polyblend	80	Nitrile/Vinyl Polyblend	11
Nitrile/Vinyl Polyblend	100			Chloro-sulfonated polyethylene	79	Microcellular	9

APPENDIX I

Test Compounds Formulae

	FP-1	FP-2	FP-5	FP-21	FP-24
Pale Crepe	100.	--	--	--	--
SBR-1502	--	100.	--	100.	--
Hycar 1001	--	--	100.	--	--
Neoprene W	--	--	--	--	100.
High Styrene Resin	--	--	--	50.	--
Zinc Oxide	5.0	5.0	5.0	5.0	5.0
Stearic Acid	3.0	1.0	1.0	1.6	--
Sun-Check Wax	--	--	1.0	--	--
XLC Mag. Ox.	--	--	--	--	0.5
Diethylene Glycol	1.0	4.0	--	--	--
Cumar Resin	--	5.0	--	13.	7.0
Circo Lt. Oil	--	--	--	9.	20.0
TP-90 Plasticizer	--	--	10.0	--	--
Hisil 233	30.	30.	35.	65.	40.
Silene EF	--	--	--	--	30.
SRF Black	3.0	3.0	3.0	0.05	0.5
TiO_2	--	--	--	4.25	--
Yellow Iron Oxide	--	--	--	2.00	--
Red Iron Oxide	--	--	--	0.60	5.0
Octamine	1.0	1.0	1.0	2.00	2.00
M.B.T.S.	0.8	1.2	1.5	1.54	0.5
T.M.T.M.S.	--	0.25	--	0.73	--

APPENDIX I (cont'd)
Test Compounds Formulae

	FP-1	FP-2	FP-5	FP-21	FP-24
D.O.T.G.	1.2	--	--	--	1.5
D.P.G.	--	--	--	1.45	--
Diethyl Thiourea	--	--	--	--	2.0
Sulfur	2.0	3.0	1.5	1.97	--
Cure	20' @ 287°F.	20' @ 300°F.	20' @ 310°F.	8' @ 320°F.	10' @ 287°F.

APPENDIX II
Experimental DMS Formulae

	SBR-1	NV-2	NBR-3	CR-4	Micro-5
SBR-1502	90.	-	-	-	-
Nitrile/Vinyl Polyblend	-	100	-	-	40.
Nitrile Polymer	-	-	90.	-	-
EPDM Polymer	20.	-	-	-	-
Chlorosulfonated Polyethylene	-	-	-	15.	-
Polybutadiene	-	-	-	15.	25
Oil-Extended Polybutadiene	-	-	14.	-	48
Neoprene W	-	-	-	70.	-
Hi-Styrene Resin	-	-	-	-	10.
Zinc Oxide	-	3.0	3.0	5.	3.
Stearic Acid	1.0	1.5	1.5	1.0	1.5
Sunproof Wax	-	1.0	1.0	-	1.0
Petrolatum	-	-	-	-	4.0
Sundex 53	10.	-	-	-	-
Turgum S	-	3.0	-	-	-
Metalyn 100	-	20.0	-	-	-
Plasticizer 3705	-	-	20.	-	-
P.E.G. 4000	-	-	1.5	2.0	1.5
Polymel DX-10	-	-	-	15.	-
P.E. 617A	-	-	-	2.0	-
D.O.P.	-	-	-	-	25.
Arizona 208	-	-	-	22.5	-
Hi Sil 233	50.	45.	45.	55.	55.

APPENDIX II (Cont'd)
Experimental DMS Formulae

	SBR-1	NV-2	NBR-3	CR-4	Micro-6
Carbon Black	3.	3.	3.	5.	3.
U.O.P. 88	1.0	-	-	-	-
Agerite Resin D	1.0	-	-	-	-
Flexzone 3C	1.5	-	2.0	-	-
Octamine	-	1.0	2.0	-	-
Thermoflex A	-	-	2.0	2.0	-
Aminox	-	-	-	-	2.0
M.B.T.	1.5	1.5	0.5	-	1.5
D.O.T.G.	0.5	0.5	0.25	0.5	0.8
Methyl Zimate	1.0	0.5	0.5	-	0.8
M.B.T.S.	-	0.5	-	-	-
T.M.T.D.S.	-	-	0.25	0.5	-
XLC Mg O	-	-	-	4.0	-
NA 22	-	-	-	0.5	-
Sulfur	2.5	1.5	1.25	1.0	1.5
Celogen OT	-	-	-	-	3.0
Cure	10'@310°F	10'@310°F	10'@310°F	10'@310°F	10'@310°F